ESS HPRF Distribution: Technology Enhancement for High Temperature RF Loads

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Many thanks to

✓ Suppliers:

✓ Colleagues:

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FREIA: Rolf Wedberg, Lars Hermansson, Roger Ruber & other colleagues

CERN: Eric Montesinos, Olivier Bruner

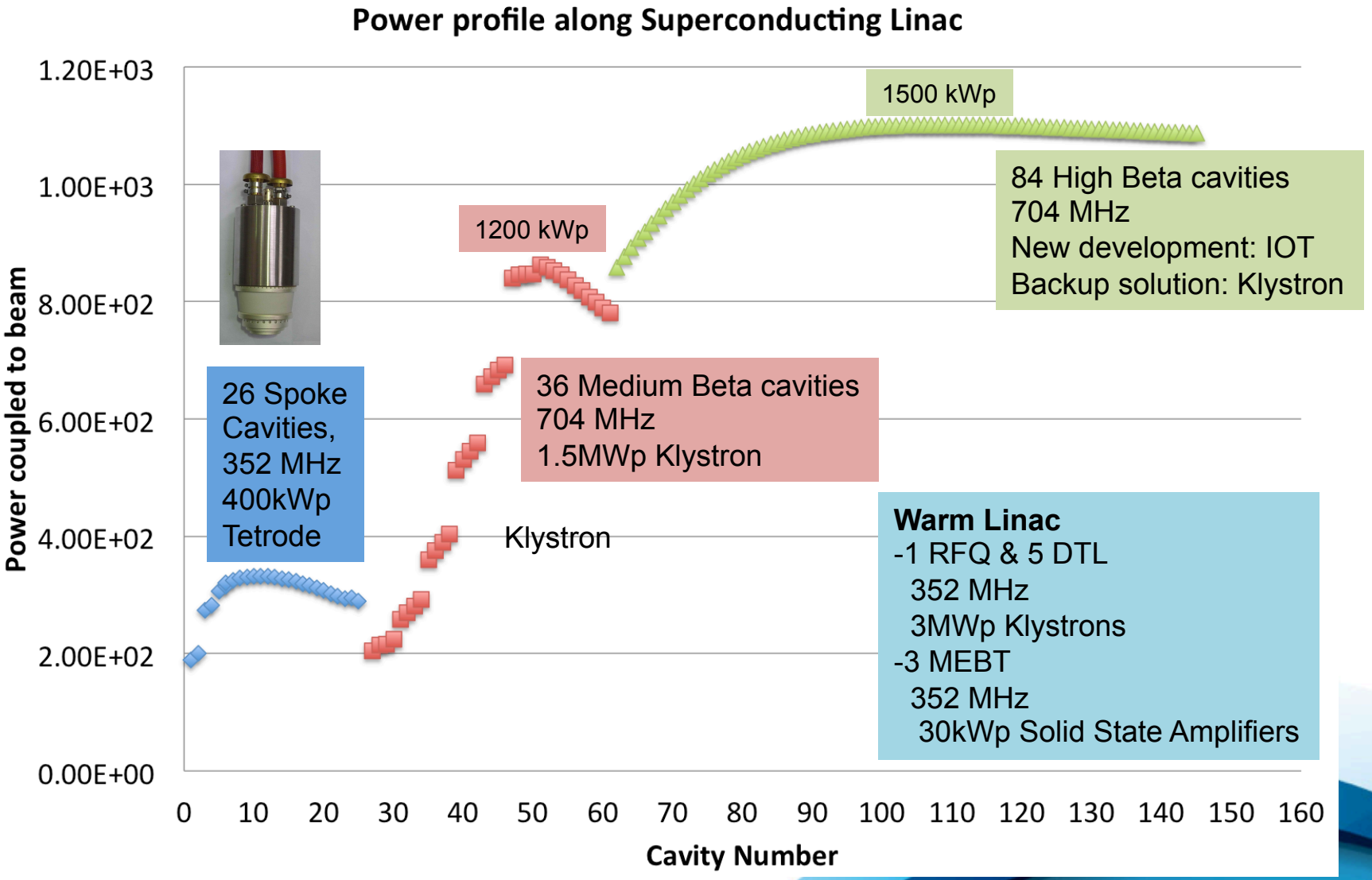
SNS: Crofford Mark

EUROPEAN SPALLATION SOURCE

Overview:

- ESS RF systems
- Earlier plans for Load Cooling
- Present plans for High Temperature cooling
- Technology enhancement & New Developments
  * Resistive Loads
  * Ferrite ER Load
  * Ferrite load (ferrite tiles)
  * Water Load

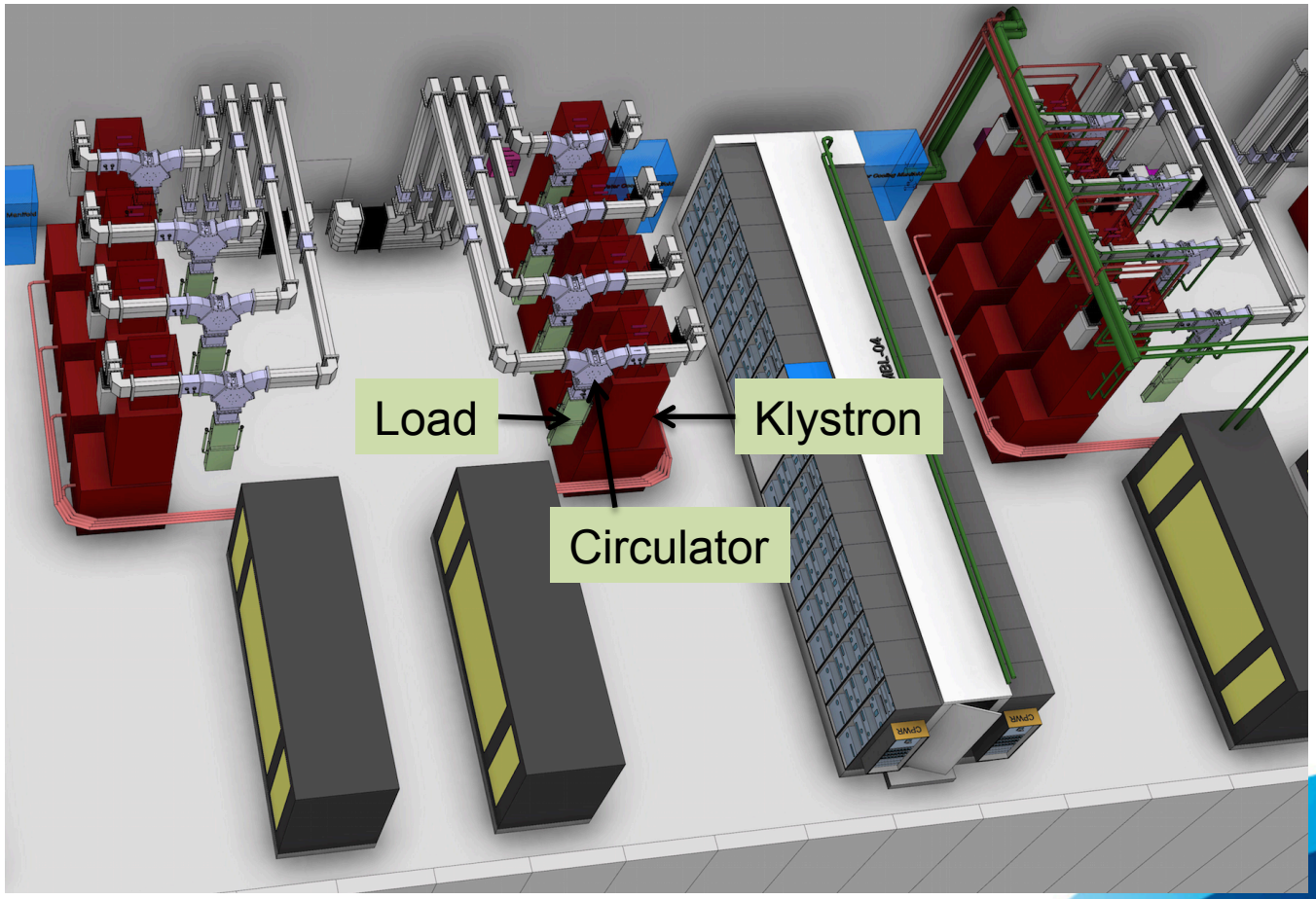
ESS HPRF Systems



RF Loads

RF loads: Matched terminations

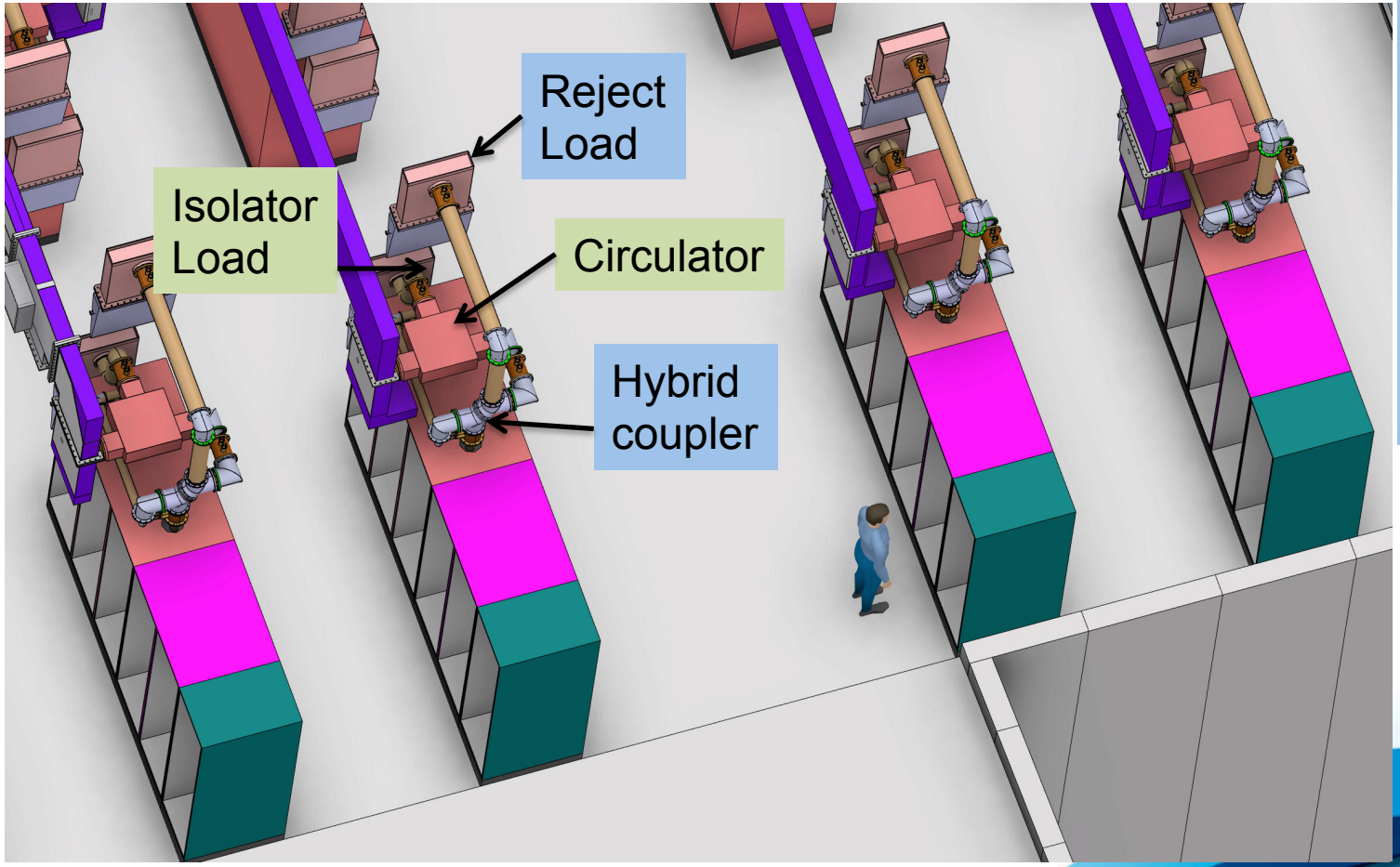
Isolator Load: Used with circulator to protect amplifier
To dissipate RF power during Amplifier testing



HB/MB Linac

100 loads
Frequency = 704 MHz,
Power = 1.5 MWp
(Isolator loads)
Flow requirement:
70 lpm x 100

Reject load: RF load with 3 dB Combiner (Hybrid coupler)

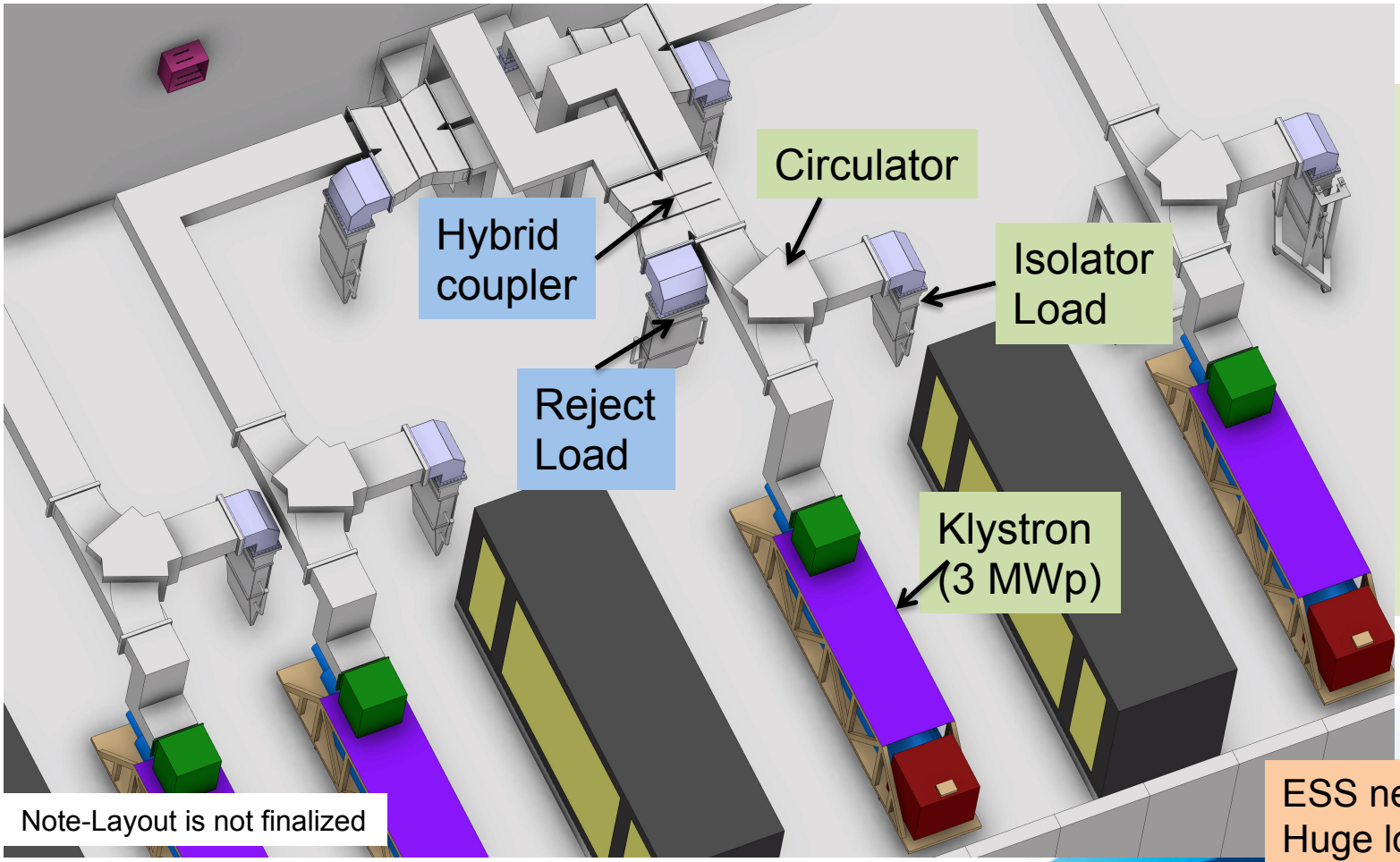


Spoke Section:

52 Loads
352 MHz
Isolator loads:
400 kWp,
Qty: 26
Reject loads:
100 kWp,
Qty:26
Flow requirement:
30 lpm x 100

Courtesy: FREIA

- RF load with 3 dB Splitter (Hybrid coupler) as Reject load:



Note-Layout is not finalized

RFQ/DTL

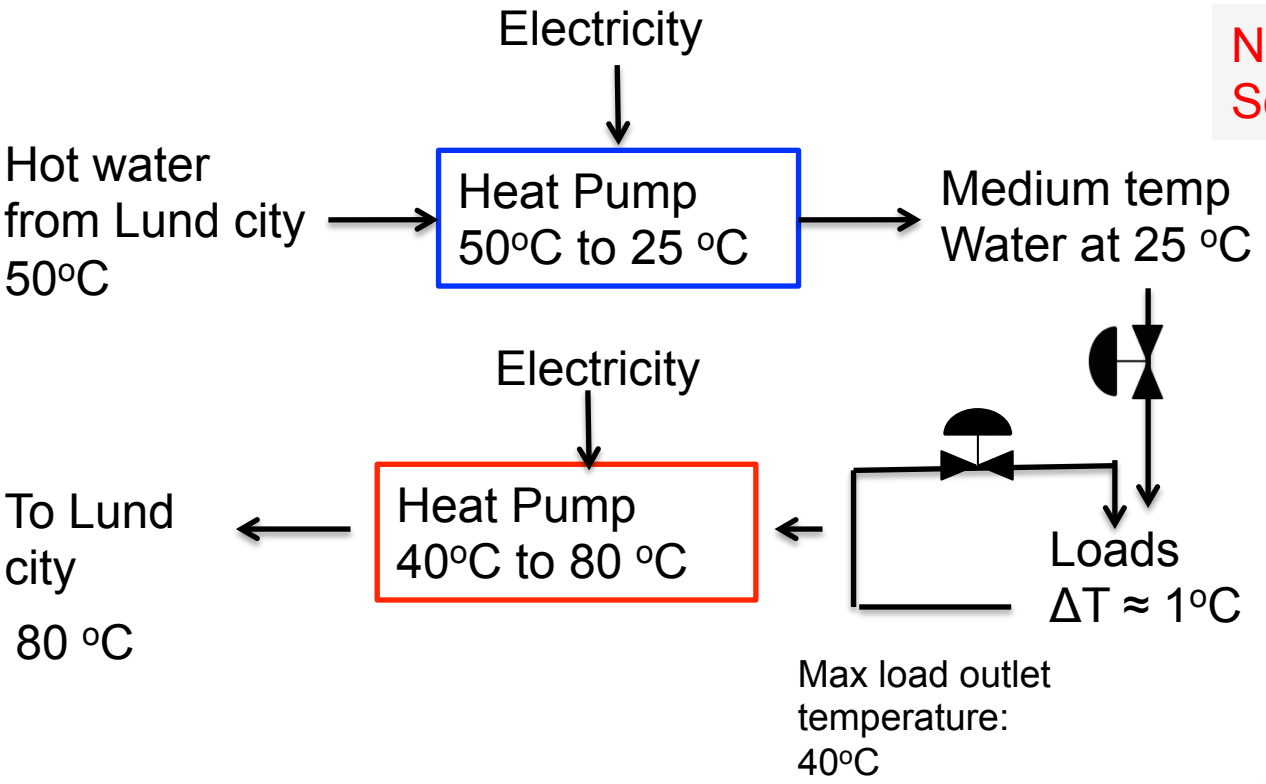
12 Loads
352 MHz
Isolator loads:
3 MWp,
Qty: 6
Reject loads:
0.75 MWp,
Qty:6
Flow requirement:
135 lpm x 12

ESS needs 170 loads !
Huge load requirement
Huge flow requirement

Earlier Plans for Load Cooling

ESS will have three cooling circuits: 10°C, 25°C, 50°C

Loads **were** on medium temperature circuit ie. 25°C



Not energy efficient Solution !

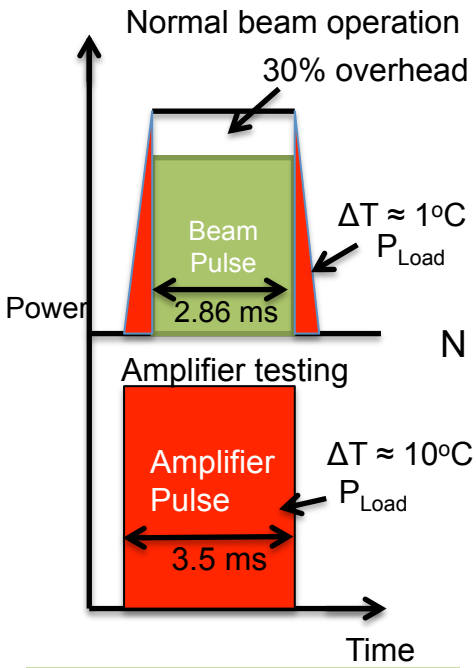
Decided to have loads on 50°C cooling circuit

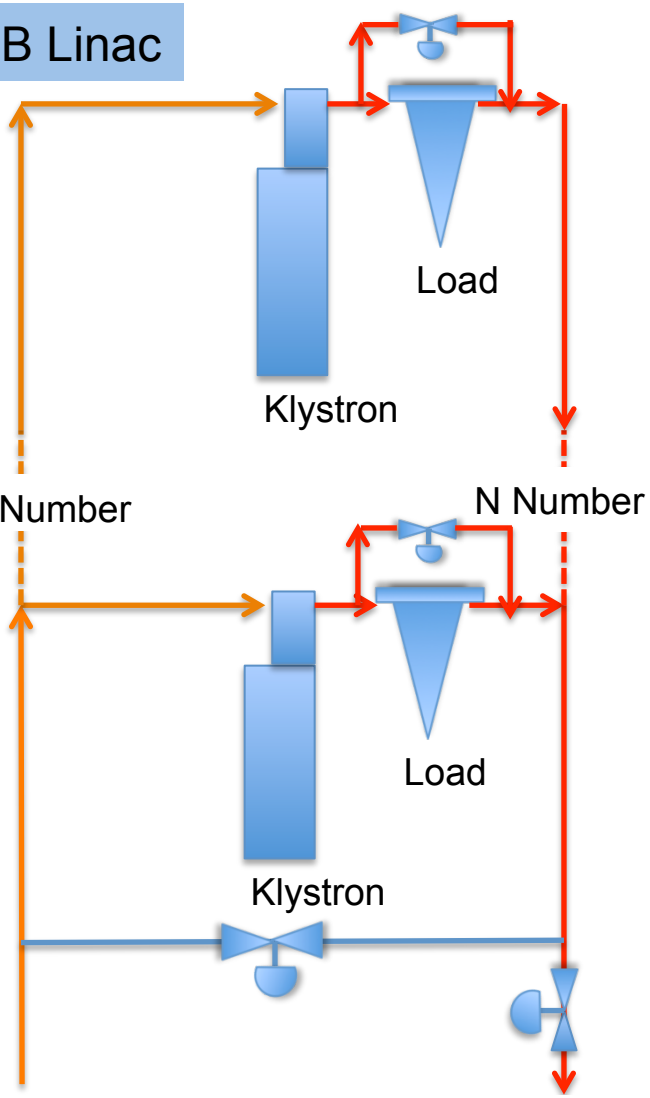
Components shall be in series without affecting Reliability.

Hence technology enhancement !

New Cooling Concept (22 Jan 2015)

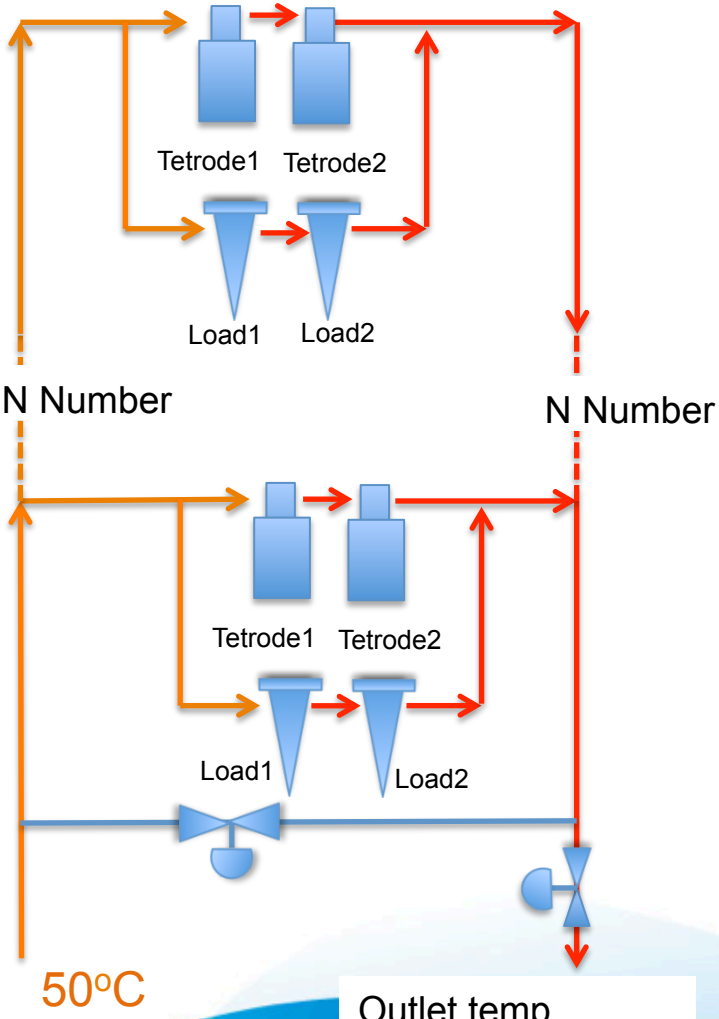
HB / MB Linac





But reliable, low maintenance loads **were not** existing with minimum 50°C inlet and 80°C outlet !!!

Spoke Linac



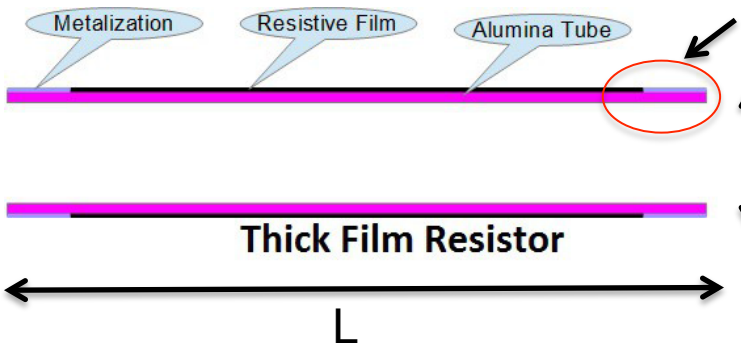
Courtesy:
Cooling task force,
Morten Jensen

Resistive loads

Technology Enhancement

Maximum outlet temperature 90°C

Maximum power load available today = 200 kWp



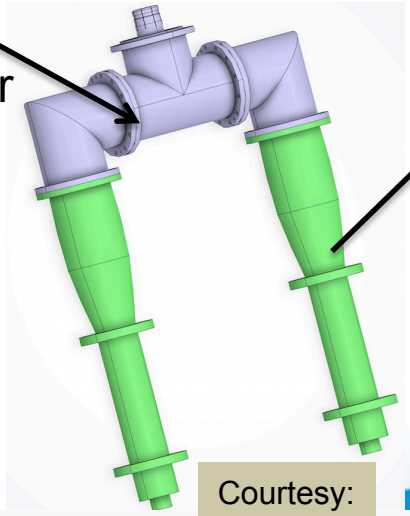
d α Ip

L α Average power

Metallization: provides rf contact to the resistive coating

For spokes: 400kWp

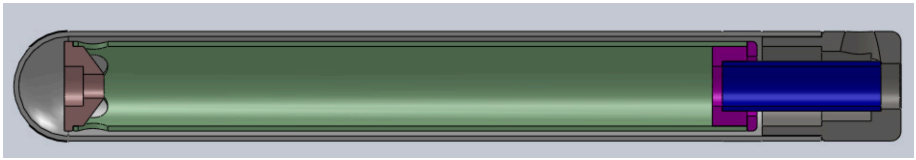
Indigenously Developed TEE combiner



Courtesy: FREIA

Courtesy: FREIA

New resistor being developed for ESS: 750 kWp @ 704 MHz



d ≈ 8 inch, L ≈ 28 inch

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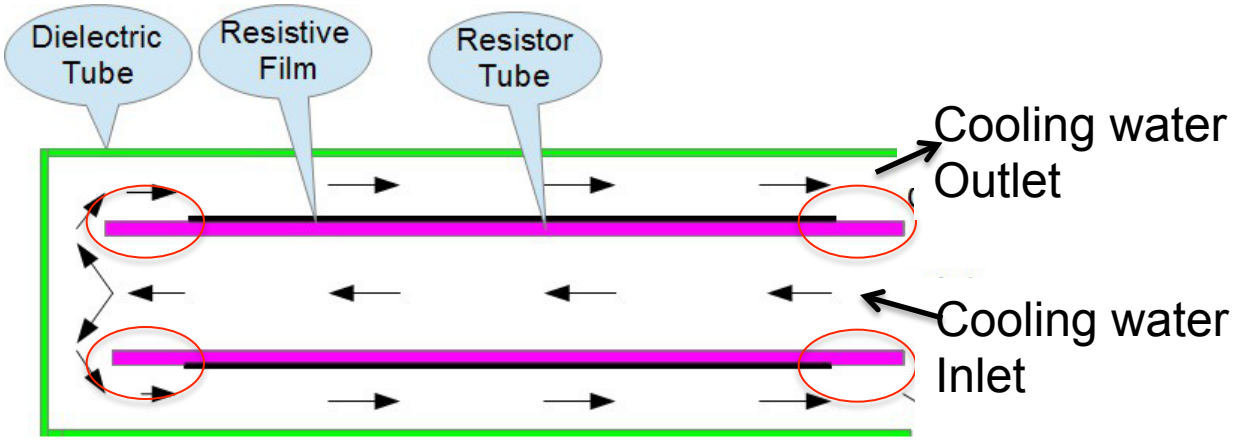
Resistive loads



Needs maintenance !

In spite of Gold plating, after three years, resistor need to be replaced.

Courtesy: Doug Horan (ANL)

Heat removal is efficient

Corrosive effects of high-purity DI water causes erosion of rf contacts. Thus resistor needs to be replaced.

To avoid fast erosion: The RF contacts are plated with Gold.

-Increase in running cost of accelerator
-Increase in Man power requirement

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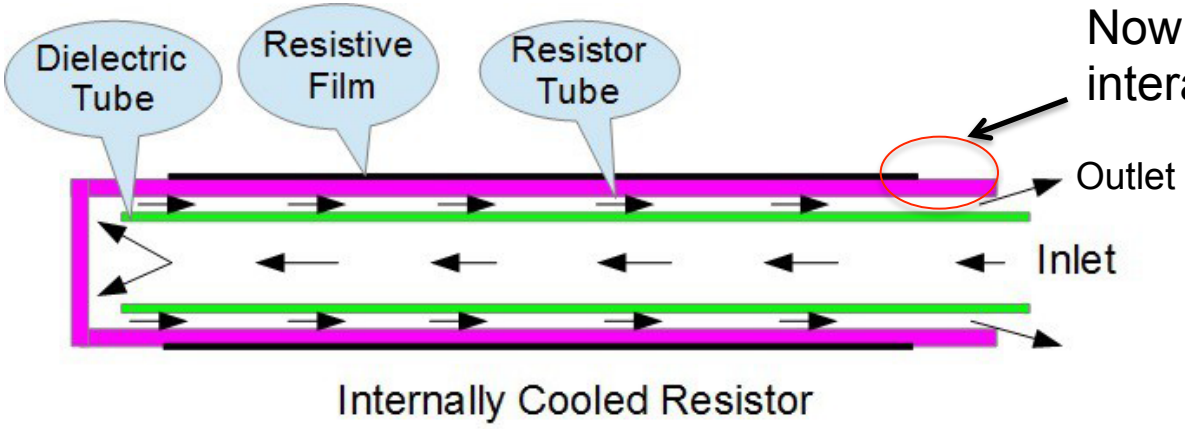

Now DI water no more interacts with metallization

Thus needs zero maintenance !

- Heat removal is less efficient compared to earlier design
- Load becomes more compact as dielectric tube inside ceramic

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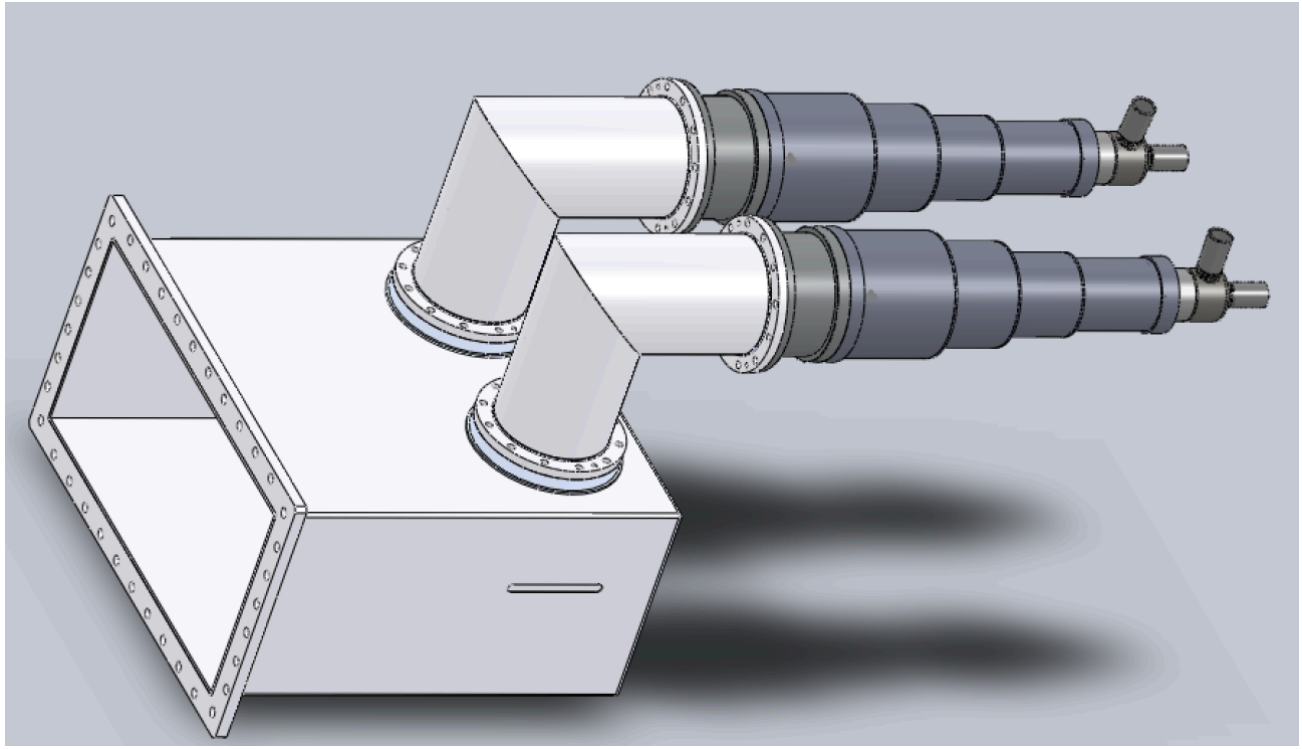
Proposed design
For HB/MB load

- New resistor Development
- Zero maintenance



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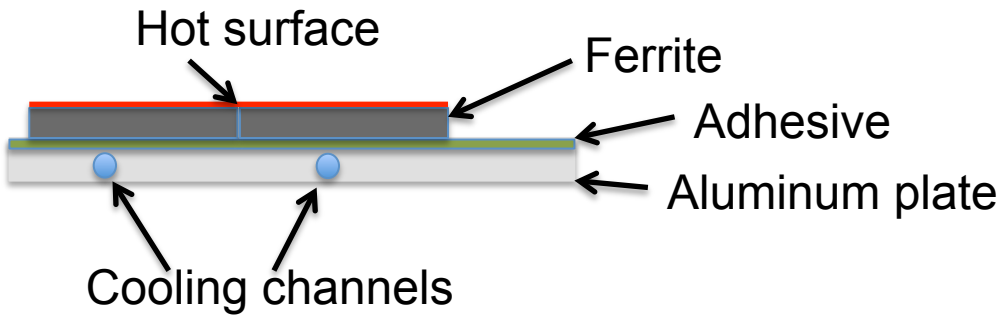
EUROPEAN SPALLATION SOURCE

Ferrite Load using ferrite tiles

- Ferrite tiles glued with water cooled wall
- Zero maintenance
- RF and water circuit separate

Earlier Maximum return temperature ≈ 40°C



AFT changed gluing technology
- To take care of heat transfer to the cooling channels
- Adhesive withstands >> 80°C
- To tare care of different thermal expansions of ferrite and Al, thermal stresses

Now outlet temperature = 80°C

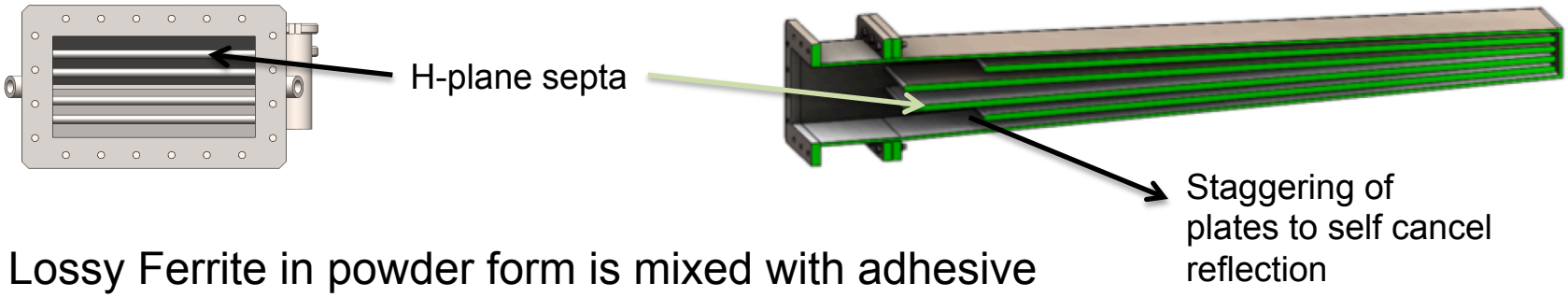
AFT microwave

New development for ESS

Ferrite Energy Recovery Load

Max Outlet temperature 80° C Lossy ferrite powder used as absorber

Development by MEGA, following merger of MCI into MEGA
(Basic R&D was carried in CERN by Fritz Casper for loads at high frequency)



Lossy Ferrite in powder form is mixed with adhesive
Applied on water cooled Septa

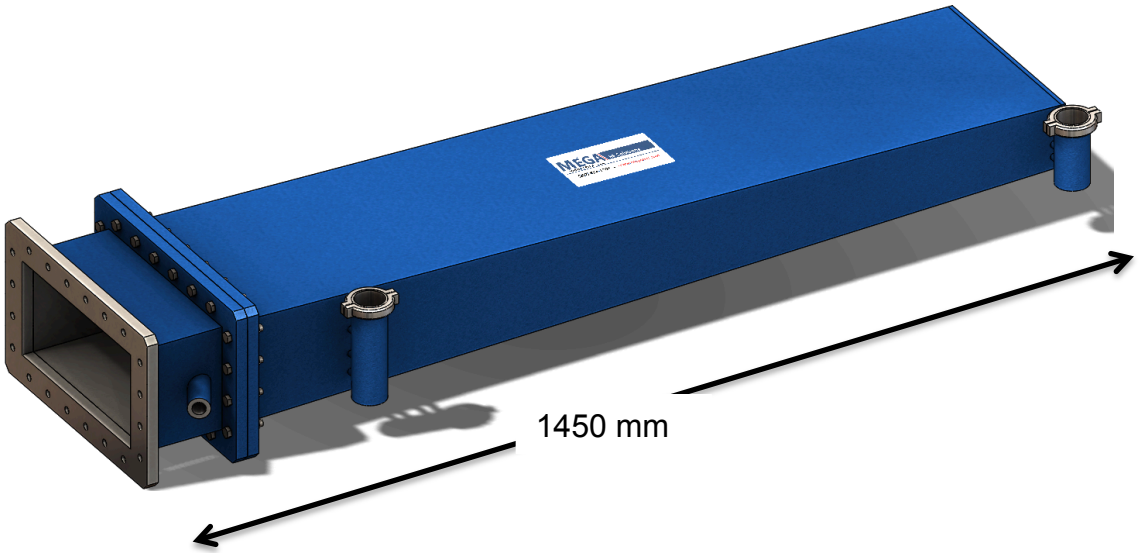
- ✓ Eliminates risk of fracture due to thermal stresses ↗
- ✓ As ferrite molecular density is reduced, Watt /area reduces ↘
- ✓ Surface area increases, thus increasing avg. power handling capability ↗

MEGA RF Solutions INDUSTRIES, LLC

EUROPEAN SPALLATION SOURCE

Proposed design for HB/MB load

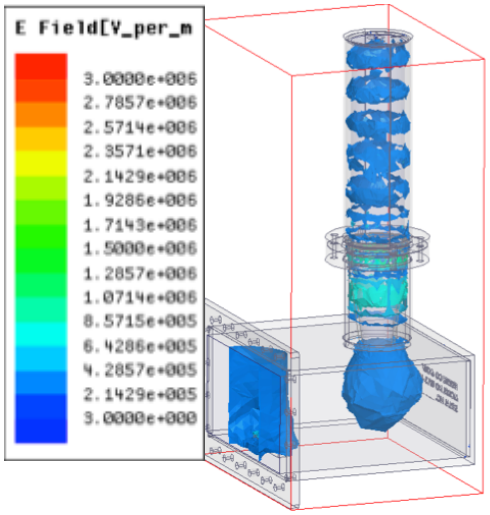
- Zero maintenance
- RF and water circuit separate



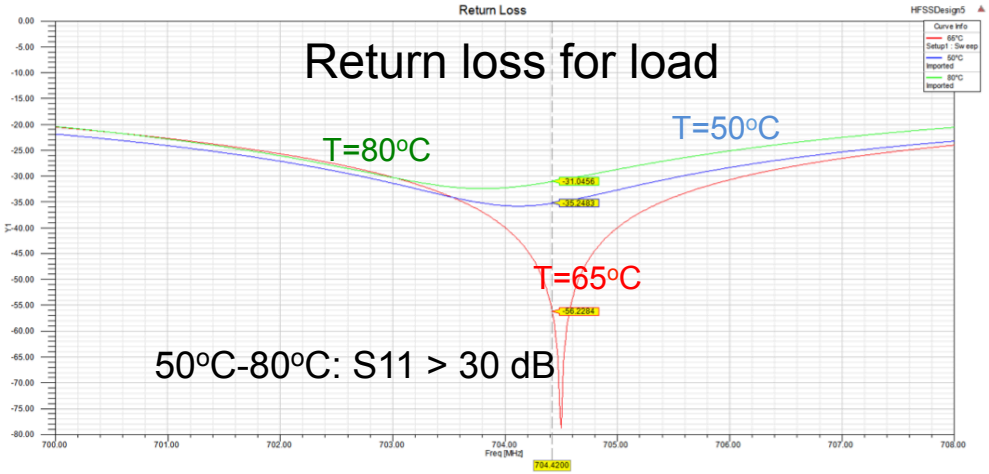
MEGA RF Solutions INDUSTRIES, LLC

Water Load

DI water is used as absorbent

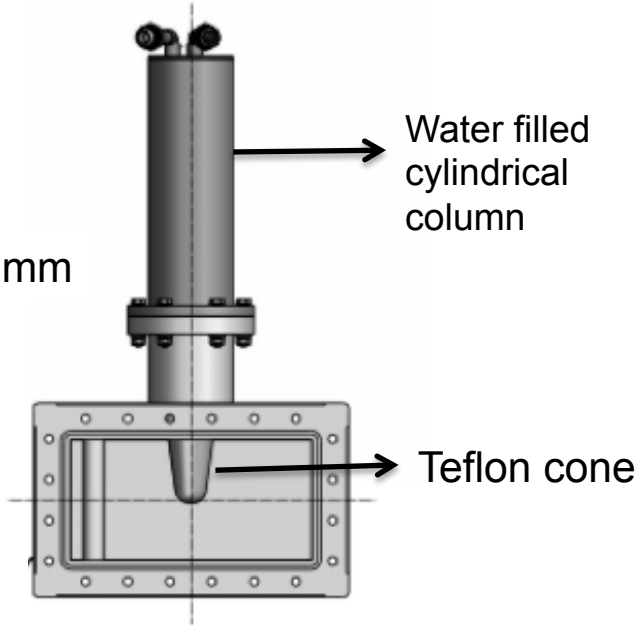


E field < 0.8 MV/m
For input power 1500 MWp



Proposed design for HB/MB load

Length≈ 700 mm



ESS will be first one to use high temperature water cooled loads for **Energy recovery.**

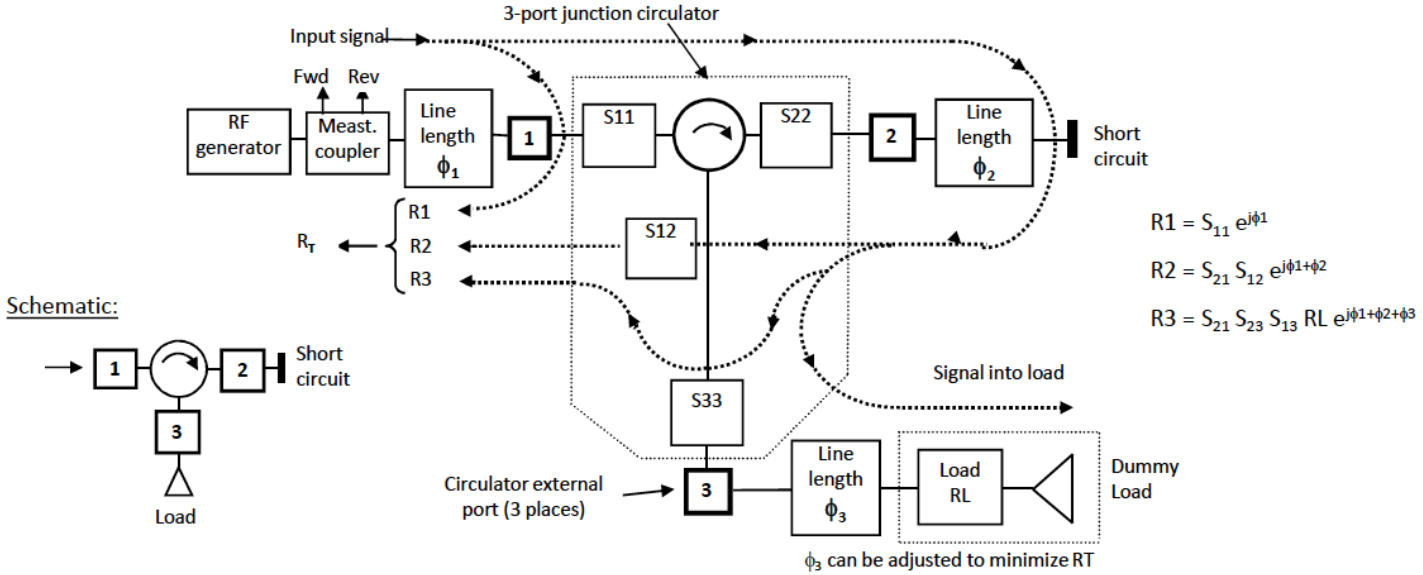
The load designs are either NEW or with TECHNOLOGY ENHANCEMENT !

RF GROUP IS TAKING RISK

Thank you !

Notes on Isolation

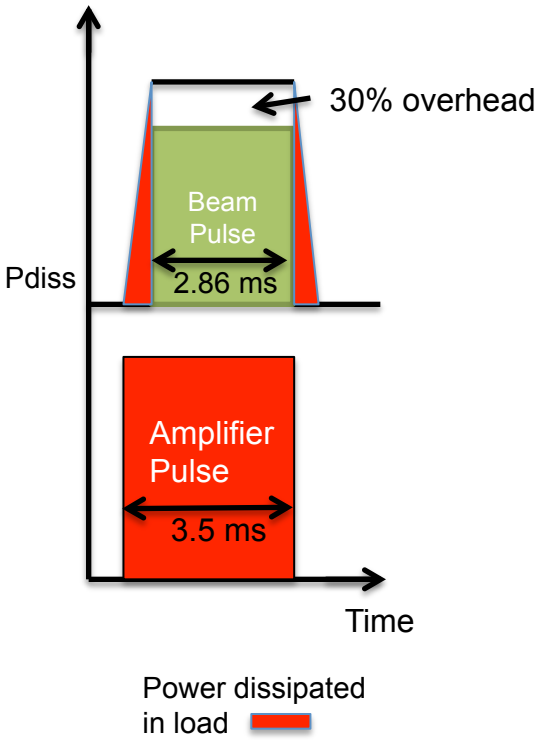
Isolation of a Circulator Shorted at Port 2, Load at Port 3



$R_T = R1 + R2 + R3$ $\quad R_{T,max} = |S_{11}| + |S_{12}| + |RL|$

The reflection coefficient R_T seen by the RF generator depends on the circulator S_{11} and the intrinsic isolation S_{12} but also on reflection coefficient R3 of the dummy load!

Different Operating scenarios



Power to the load during matched Beam operation

6000 hours/year: When machine is running

Increase in outlet temperature < 1^{o}C

Power to the load during Amplifier testing

Testing time < 600 hours / year

Increase in outlet temperature ≈ 10 ^{o}C

Time